National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOAA *by the* NUMBERS

NOAA's Value To The Nation

June 2018

Chief Economist Team
Performance, Risk and Social Science
Office of the Chief Financial Officer

performance.noaa.gov/economics

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On the Cover:

A biologist records algal diversity within a photoquadrat during an underwater survey at Midway Atoll. Hawaii, Northwestern Hawaiian Islands. 2006 September 15. Photographer: Dr. Jean Kenyon, NOAA/NMFS/PISC/CRED. Flickr

Foreword

Colleagues, Partners, and Friends,

We have developed *NOAA by the Numbers* to document the tremendous return on the investment provided to NOAA by the American people. Use this outstanding report when you communicate to our stakeholders externally, and prioritize your work internally.

This metrics in this report serve as measures of performance in achieving NOAA's two priority objectives:

1. minimize the impacts of extreme weather and water events by implementing the Weather Research and Forecasting Innovation Act, with the underlying goal to regain world leadership in weather modeling; and
2. accelerating the the American Blue Economy, with specific focus on reducing the nation's seafood trade deficit through expanded marine aquaculture.

Achieving these objectives supports the Department of Commerce's Strategic Plan, and ensures NOAA improves in performing its critical mission of saving lives, protecting property, and advancing our economic, national, natural, and homeland security.

As the data in *NOAA by the Numbers* shows, we are making extraordinary progress in achieving these objectives, and every single NOAA employee should be proud. This is why I'm convinced that NOAA is the leading agency - by a longshot - in transitioning cutting edge science and technology to benefit the lives of the American people.

With gratitude and respect,

RDML Tim Gallaudet, Ph.D., USN Ret.
Assistant Secretary of Commerce for Oceans and Atmosphere and
Acting Under Secretary of Commerce for Oceans and Atmosphere
National Oceanic and Atmospheric Administration
Washington, D.C.
June 2018

Acknowledgments

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If you have questions, comments or feedback, please write an email to us at **monica.grasso@noaa.gov** or call at 240 - 533 - 9036 (Silver Spring Headquarters).

National Oceanic and Atmospheric Administration
Chief Economist

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June 2018

TAS on NOAA Ship PISCES. NOAA Dart Tsunami Warning Buoy being secured for maintenance. NOAA's National Weather Service (NWS) Collection Photographer: Lesley Urasky, Rawlins HS, Rawlins, WY Credit: NOAA Teacher at Sea Program

Disclaimer

This document presents statistics extracted from NOAA and non-NOAA studies provided by NOAA's line offices. The statistics provided to the Chief Economist Team were checked against original sources, but there were no attempts to reproduce or peer review the numbers in the studies. Each section includes sets of statistics.

In this document, the NOAA Chief Economist Team present the most current information available. For some older studies, we have adjusted original monetary amounts to 2016 values using the annual gross domestic product (GDP) deflator as recommended by the Office of Management and Budget (OMB) Circular A-4. Not all values were updated because in some cases, original price levels could not be determined or the statistics were part of a time series report with upcoming updates.

VORTEX2 field command vehicle in vicinity of thunderstorm. Kansas. 2009 June 9. Photographer: Dr. Mike Coniglio, NOAA NSSL. Credit: VORTEX II.

NOAA and Value Creation

NOAA's mission is to "to understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources".[1] In fulfilling its mission, the agency's programs create significant economic value. NOAA's research and forecasts lead to reduced damage from storms and other natural hazards. The agency provides information that helps businesses make decisions and allows key industries like transportation and agriculture to operate more efficiently. NOAA's management programs for oceans and coastal areas help enhance both the current and future productivity of these economically vital resources.

It is not possible to distill all of NOAA's economic impacts to the nation — and the world — into a single number. The different services that NOAA provides affect the economy in diverse ways, and there are a variety of techniques that economists use to measure the effects of those services.

NOAA by the Numbers provides a summary of statistics and findings of recent research that either directly measure economic benefits of particular programs, or indicate the general context in which particular NOAA programs create economic value.

How NOAA Contributes to the U.S. Economy

NOAA contributes value to the economy in two fundamental ways. First, by providing information that people find valuable and that people use to guide or influence decisions, and second, by managing, or helping to manage, natural resources that are themselves valuable. Understanding the economic worth created by NOAA involves asking how people use/value the information that NOAA provides, or how the values of resources are enhanced through NOAA management.

Value of the Information that NOAA Provides

Information that NOAA provides is placed into two general classes: (1) operational information; and (2) research information. Both kinds of information derive their value from the ways people use the information, but there are significant differences in the challenges in estimating their values.

Operational Information

Much of the information created by NOAA is "operational" in nature, including the full range of weather information together with ocean conditions and forecast information.

Such information is valuable because people, businesses, academia, and governments use it regularly to improve decision making. They use it to make critical decisions about preparing for storms, such as future electricity demands as well as to make individual decisions about personal plans.

Operational information is valuable when it is accurate and timely. Accuracy means the information is correctly presented and predicted. Timeliness means that the information gets to people and organizations in a timely manner to ensure appropriate responses.

The value of operational information lies in the use of information to improve economic, social, and other societal outcomes. Thus, the value or worth of information also depends on:

- The ability to use information to make a better decision (regardless of the preciseness or timeliness, information has no value if there is no way to act);
- The perceptions of the users (do they trust the information enough and have the ability to act upon the information); and,
- The potential economic and/or societal gain or loss resulting from a good or bad decision.

[1] National Oceanic and Atmospheric Administration (2008). Retrieved from noaa.gov/our-mission-and-vision

Storm forecasts are one example of the operational information NOAA provides. The forecasts enable people to respond in ways that limit the costs of storms. To measure this type of value, economists try to assess the life and property damages that could result from storms and to assess how information coupled with changes in behavior reduces those damages.

This damage reduction is the value created by the information. Important examples of storm forecasts include tornado and hurricane warnings. Such warnings have huge impacts on morbidity and mortality reductions, both of which are reduced by proactive evacuations and sheltering in place.

In the case of hurricane warnings, an accurate forecast makes it possible to target the hurricane evacuation zone correctly and gives sufficient time to allow the evacuation to be safe and orderly. This is important because evacuations can be costly, but the failure to evacuate or seek shelter may have greater consequences.

Research Information

Research in a number of fields is also a key part of the information that NOAA provides. NOAA is a world leader in weather and climate research and in all aspects of oceanographic research. NOAA's environmental research is critical to a wide variety of activities and decisions in the U.S. and around the world.

A good example is research that improves the precipitation forecasts that are used by farmers to decide which crops to plant and when and how much to irrigate, reducing their costs and increasing agricultural productivity.

In some cases, measuring the economic value of research is relatively straightforward, as when a scientific finding is used directly in operational or engineering applications. But in most cases, measuring the economic value of NOAA's research programs is more difficult; the transformation of research into human activities that have economic value often takes a great deal of time, and the connections between specific research and outcomes are hard to trace.

Academics, federal agencies, and regional and local community managers are using NOAA's products and services to gain a better understanding of climate change and its effects. However, the effects of climate change and the best policies to mitigate these impacts are not fully understood, therefore it is difficult to measure the economic value of NOAA services.

Value of NOAA Resource Management Activities

In cooperation with other federal agencies and with state and local governments, NOAA assists in the management of the diverse and complex human and natural ecosystems of the U.S. coastal areas, including the Great Lakes and rivers. Enhancing the values of these natural resources means dealing with complex tradeoffs among competing resource uses using state of the art environmental information and decision support tools.

NOAA's management activities enhance the value of various resources. For example, NOAA creates value through policies that prevent overfishing and the subsequent decline of key fish stocks, which would reduce the value of the fishing industry and the values to consumers of seafood products. NOAA also manages a network of protected areas in estuaries and in coastal waters.

Columbia River Estuary seine sampling for juvenile Chinook salmon for mark- recapture to evaluate residency time. Seine boat and crew. Planning next step. Oregon, Columbia River, Russian Island. 2006 April 4. Photographer: Benjamin Sandford, NOAA/NMFS/NWFSC/FED/PF.

Contribution to U.S. Income, Employment and Output

General Statements Related to NOAA's Products and Services

- Each day, nearly every American relies on the data, products, and services NOAA provides. These products and services include daily weather forecasts, navigational tools to support the country's nearly $4.6 trillion in economic activity generated by U.S. seaports[2], assessments on the health of the nation's $200 billion fisheries[3], and disaster response. For example, Lazo et al. (2011), found that GDP varies 3.4 percent from year to year due to weather; this equated to $485 billion per year in 2008 (the figures cited in the study)[4] or $545 billion in 2016.[5] Variability can be positive or negative.
- Businesses that are directly dependent on the oceans and Great Lakes resources contribute more than $350 billion to the nation's GDP, supporting more employment than crop production, telecommunications, and building construction combined.[6]
- In 2015 alone, 1.39 billion short tons account for $1.56 trillion worth of U.S. goods that moved through U.S. ports. Imports and exports via water represented 71 percent of U.S. imports and exports by weight and almost 42 percent of cargo value in 2015.[7]

Weather Forecasts and Warnings

- A nationwide survey indicates that weather forecasts generate $31.5 billion in economic benefits to U.S. households ($35 billion in 2016).[8]
- The sum of all federal spending on meteorological operations and research was $3.4 billion, while an additional $1.7 billion ($1.9 billion in 2016) was spent on weather forecasting by the private sector, totaling $5.1 billion spent on public and private sector weather operations and research in 2009. This suggests that the value provided by weather forecasts to households was 6.2 times the cost of producing the forecasts.[9]

A National Weather Service meteorologist in Norman, Oklahoma, tracks a super cell tornado outbreak. (NOAA)

[2] Martin Associates. (2015, March). 2014 National Economic Impact of the U.S. Coastal Port System. Report prepared for the American Association of Port Authorities. Retrieved February 24, 2017, from aapa.files.cms-plus.com/PDFs/Martin%20study%20executive%20summary%20final.pdf

[3] National Marine Fisheries Service. (2016). Fisheries Economics of the United States, 2014. U.S. Department of Commerce, NOAA Technical Memorandum No. NMFS-F/SPO-163, 237 p. Washington, D.C.: U.S.

[4] Lazo, J.K., Lawson, M., Larsen, P.H., and Waldman, D.M. (2011). United States Economic Sensitivity to Weather Variability. Bulletin of the American Meteorological Society, p.710. DOI:10.1175/2011BAMS2928.1.

[5] Computed as 3.4 percent of GDP in 2016.

[6] Ache, B. W., Crossett, K. M., Pacheco, P. A., Adkins, J. E., & Wiley, P. C. (2015). "The coast" is complicated: a model to consistently describe the nation's coastal population. Estuaries and coasts, 38(1), 151-155. Available at: coast.noaa.gov/data/digitalcoast/pdf/qrt-coast-complicated.pdf

[7] Foxx, A., Perez, T. and Pritzker, P. (2016, March 7). U.S. Ports: Investing in Engines of Economic Development and American Competitiveness. U.S. Department of Transportation Blog. p.1. Statistics available at North American Transportation Statistics at nats.sct.gob.mx/go-to-tables/table-7-international-merchandise-trade/table-7-1-international-merchandise-trade-by-mode/

[8] Lazo, J. K., Morss, R.E. and Demuth, J.L. (2009). 300 billion served: Sources, perceptions, uses, and values of weather forecasts. Bulletin of the American Meteorological Society 90(6), 785-798.

[9] U.S. Department of Commerce, Economics and Statistics Administration. (2014). Fostering Innovation, Creating Jobs, Driving Better Decisions: The Value of Government Data, p.15.

- Satellites, marine research vessels, researchers, and data systems are the backbone of NOAA weather products and services. The products and services produced by the National Weather Service provide a foundation for U.S. business investments. For example, the Climate Corporation sells agricultural consultant services and insurance based on National Weather Service products[9]; Monsanto bought the Climate Corporation in 2013 for nearly $1 billion.[10]
- The success of the $121 billion (2016) agriculture sector (excluding forestry and fisheries) depends on accurate forecasts for planting, irrigation, and harvesting. These agriculture decisions are informed by NOAA's forecasts, driven by models that receive air and water observational data from NOAA infrastructure.[11]
- On October 1, 2007, NOAA converted to issuing storm-based warnings (SBWs): meteorologists designed a unique warning area (shaped as a polygon) that projects the general path they expect a tornado or potentially tornadic storm cell to take.[12]In tests during 2004–05, SBW reduced the area covered by tornado warnings relative to conventional county-based warnings by 70 to 75 percent. Adjusting for warning response, the authors estimated that SBW can save 66 million person-hours per year from sheltering in place, valued at a savings of $750 million.[13] Sensitivity analysis suggests that with SBWs the value of time spent sheltering saved approximately $500 million ($550 million in 2016).[13] This assessment, however, assumes that the NWS, emergency managers, and the media will disseminate the message only to those individuals located within the polygon and not continue to warn broad swaths of territory. According to the authors, the current state of warning dissemination systems cannot support this assumption and the figures they publish are to be considered potential benefits of SBWs.[13]

National Weather Service IMET Brent Wachter aiming / positioning the Direcway satellite dish. Once positioned correctly, the IMET can then download much needed weather data. 2006 April 14. Photographer: J. Brent Wachter, OAA/NWS/WFO/Albuquerque, NM.

- Weather causes nearly half of all aviation accidents. Economic losses due to aviation delays caused by weather are estimated to be more than $1 billion per year.[14] Aviation weather forecasts for both domestic and international airspace are issued by NOAA's Aviation Weather Center in Kansas City, Missouri. In addition, individual Weather Forecast Offices (122 total) distribute up to 4,000 forecasts for both aviation and in-flight forecasts each day. The Aviation Weather Center also produces graphical products that supplement aviation forecasts to display dangerous weather conditions (including thunderstorms, ice and turbulence) that may cause delays, cancellations or turn a flight into a life-threatening experience. Marine warnings and forecasts help to avoid significant losses in maritime shipping industries. For example, a study suggested that forecasts could potentially result in $135 million in savings from avoided losses for both the North Atlantic and North Pacific container trade industries.[15]

[10] Tsotsis, A. (2013, October.) Monsanto Buys Weather Big Data Company Climate Corporation For Around $1.1B. Retrieved 21 March 2018, from techcrunch.com/2013/10/02/monsanto-acquires-weather-big-data-company-climate-corporation-for-930m/

[11] U.S. Department of Commerce, Bureau of Economic Analysis. (2016). Gross Domestic Product by Industry Data. Retrieved March 20, 2017, from bea.gov/industry/gdpbyind_data.htm

[12] Sutter, D. and Erickson, S. (2010). The time cost of tornado warnings and the savings with storm-based warnings. Weather, Climate, and Society, 2(2), 103-112. Retrieved February 24, 2017, from journals.ametsoc.org/doi/abs/10.1175/2009WCAS1011.1

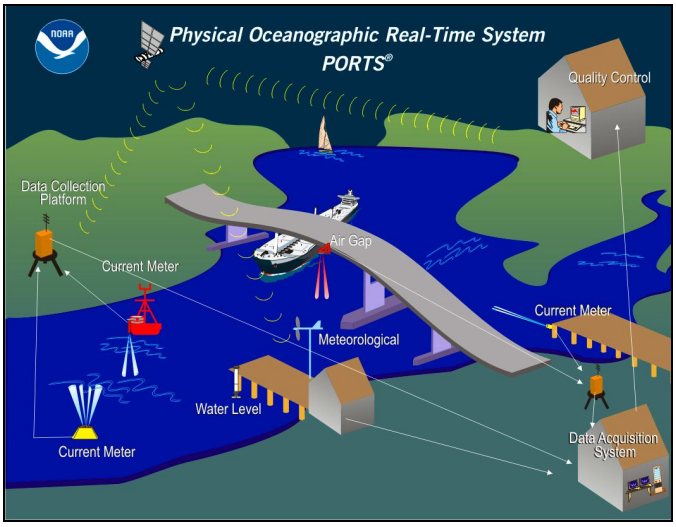
[13] Bureau of Transportation Statistics. (2017). Understanding the Reporting of Causes of Flight Delays and Cancellations. Retrieved April 4, 2017, from bts.gov/topics/airlines-and-airports/understanding-reporting-causes-flight-delays-and-cancellations

[14] National Oceanic and Atmospheric Administration (2007, April). Aviation Weather Forecasting: A History of Enhancing Air Flight Safety. Retrieved March 22, 2017, from celebrating200years.noaa.gov/foundations/aviation_weather/welcome.html#today

[15] Kite-Powell, H. (2008). Benefits to Maritime Commerce from Ocean Surface Vector Wind Observations and Forecasts. Retrieved March 4, 2017, from manati.orbit.nesdis.noaa.gov/SVW_nextgen/QuikSCAT_maritime_report_final.pdf

Coastal Ocean Observations & Related Products

- In 2014, U.S. seaports moved $1.46 trillion of goods in international cargo[16], supporting agriculture, manufacturing, retail trade and other activities with a total economic impact to the national economy that exceeds $4 trillion annually.[17]
- More than 400,000 workers are directly employed in the marine transportation sector[18] but more than 20 million jobs[17], in sectors ranging from agriculture to manufacturing and retail trade, depend on the access to international markets provided by seaports.
- As intermodal hubs for international trade, seaports are also vitally important to the $822 billion railroad and motor carrier transportation industries.[19] NOAA facilitates the shipping industry by producing accurate surveys and charts, which will become more important as the volume of traffic, and value of exports and imports in U.S. seaports is expected to double by 2021, and double again shortly after 2030.[20]
- The NOAA Physical Oceanographic Real-Time System (PORTS®) is a collection of oceanographic and meteorological instruments integrated into a system to provide accurate, reliable, real-time, quality controlled information about the environment in which mariners and recreational personnel operate.[21]
- PORTS is a decision support tool that seeks to improve the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts and other geospatial information. The PORTS program has an estimated annual cost of less than $49 million, however, the estimated return in benefits are $24 per every dollar program expenditure. The economic benefits for charting alone are $107 million.[22]



New NOAA Ocean Observing System in Pascagoula Aids Mariners; Keeps Shipping Safe

[16] U.S. Department of Commerce, Census Bureau. (2016, December). FT920 U.S. Merchandise Trade: Selected Highlights, p.1. Retrieved February 24, 2017, from census.gov/foreign-trade/Press-Release/ft920_index.html

[17] Martin Associates. (2015, March). 2014 National Economic Impact of the U.S. Coastal Port System. Report prepared for the American Association of Port Authorities. Retrieved February 24, 2017, from aapa.files.cms-plus.com/PDFs/Martin%20study%20executive%20summary%20final.pdf

[18] National Oceanic and Atmospheric Administration Office for Coastal Management. (2016). NOAA Report on the U.S. Ocean and Great Lakes Economy. Charleston, S.C.: U.S. Retrieved February 24, 2017, from coast.noaa.gov/digitalcoast/training/econreport.html

[19] Wolfe, K. E. (2016). Estimated Landside Benefits from International Waterborne Container Freight Resulting from Navigational Aids: A Scoping Study. Silver Spring, MD: National Oceanic and Atmospheric Administration.

[20] National Ocean Service. (2015). The Value of PORTS to the Nation: How Real-Time Observations Improve Safety and Economic Efficiency of Maritime Commerce. (U.S. Department of Commerce, NOAA Report) Washington, D.C.: U.S.

[21] PORTS® is managed by the Center for Operational Oceanographic Products and Services (CO-OPS) within NOAA's National Ocean Service (NOS)

[22] VOLPE National Transportation Systems Center, (2009) Valuation of the NOS Navigational Products (2009), Final Report Task 4- Benefit-Cost Analysis (BCA) Model Estimates. Intermodal Infrastructure Security and Operations Division (RVT-51), Center of Innovation (COI), Freight Logistics and Transportation Systems, Research and Innovation Technology Administration (RITA), U.S. Department of Transportation. Prepared for the National Ocean Service, under Reimbursable Agreement RA-VXD2. Dr. Bahar Barami, principle investigator, p.8.

- The annual benefit from reduced vessel transits resulting from maximized use of channel depth, reduction in vessel transit delays, enhanced oil pollution remediation efforts, reduced commercial and recreational marine accidents (collisions, allisions, and groundings) as well as enhanced fishing was estimated to reach $300 million in 2010 ($330 million in 2016), if PORTS was implemented at the top 175 busiest seaports.[23]
- The NOAA-managed National Spatial Reference System (NSRS) "improves the quality of coastal and ocean observations by providing precise measurements of latitude, longitude, and elevation."[24] The estimated benefit of these measurements is $2.4 billion ($2.7 billion in 2016) per year.[25]
- The estimated economic benefit of the NOAA Continuously Operating Reference Stations (CORS) network (which is part of NSRS and provides data to support three dimensional positioning, meteorology, space weather and geophysical applications) is $758 million per year based on the estimate of study conducted in 2009 ($844 million in 2016$).[25]

The National Spatial Reference System: Fundamental Data for Land Surveys, Nautical Charts, and the Nation's Infrastructure

- NOAA's Coastal Mapping Program (CMP) is responsible for NOAA's shoreline mapping activities, which provide critical baseline data for accurately mapping the nation's official shoreline, georeferenced disaster response imagery, and geographical reference data needed to manage, develop, conserve, and protect coastal resources. Total economic benefits from the CMP are estimated to be $241 million.[26]

NOAA's newest survey vessel is the Ferninand R. Hassler, a state-of-the-art coastal mapping vessel designed to detect and monitor changes to the sea floor. Data collected by the ship will be used to update nautical charts, detect potential hazards to navigation, and further enhance understanding of the marine environment.

- Direct benefits of the program are 15 times the actual program cost and indirect benefits are 30 times the cost of the program. At the time of this study, the CMP was estimated to support 1,500 jobs.[26]
- Volpe (2008) suggested that nautical charting and PORTS contributed a combined annual benefit of
- $1.2 billion ($1.4 billion in 2016) to the nation resulted from voyage planning, reduced vessel delays, optimal use of port capacity, averted groundings, diminished pollution releases, lessened morbidity and mortality.[27]

[23] Wolfe, K. E. and MacFarland, D. (2016). A Valuation Analysis of the Physical Oceanographic Real Time System (PORTS®), Journal of Ocean and Coastal Economics 3(1), article 12.

[24] National Geodetic Survey NOAA. (2017). NOAA Manages the National Spatial Reference System. Silver Spring, MD.

[25] Leveson, I. (2009, January). Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D. Report prepared for the National Geodetic Survey. p. 5-6. Retrieved February 24, 2017, from ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

[26] Leveson, I. (2012, March). Socio-economic study: Scoping the value of NOAA's Coastal Mapping Program. Prepared for the Remote Sensing Division of the National Geodetic Survey, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce under contract DG133C11SE1521. Retrieved 3 April 2018, from geodesy.noaa.gov/PUBS_LIB/CMP_Socio-Economic_Scoping_Study_Final.pdf

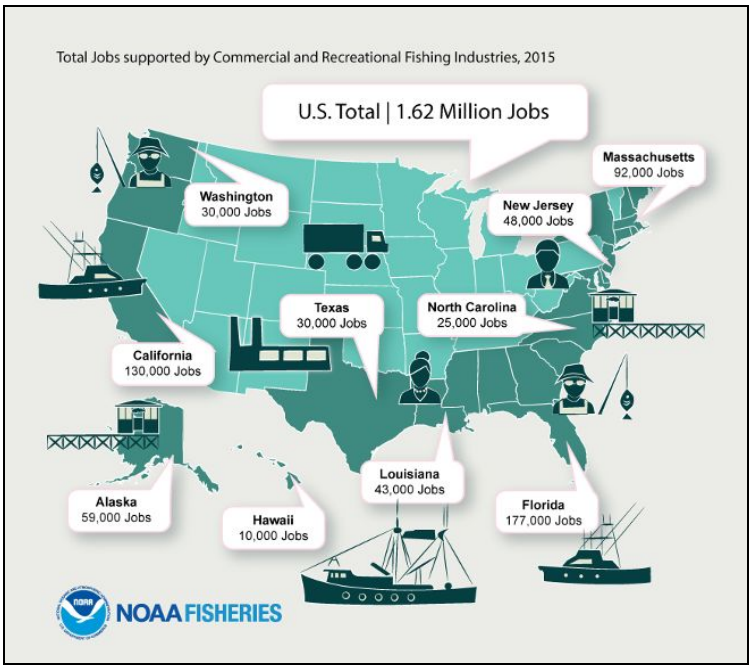
[27] VOLPE National Transportation Systems Center, (2009) *Valuation of the NOS Navigational Products (2009)*, *Final Report Task 4-Benefit-Cost Analysis* (BCA) Model Estimates. Intermodal Infrastructure Security and Operations Division (RVT-51), Center of Innovation (COI), Freight Logistics and Transportation Systems, Research and Innovation Technology Administration (RITA), U.S. Department of Transportation.

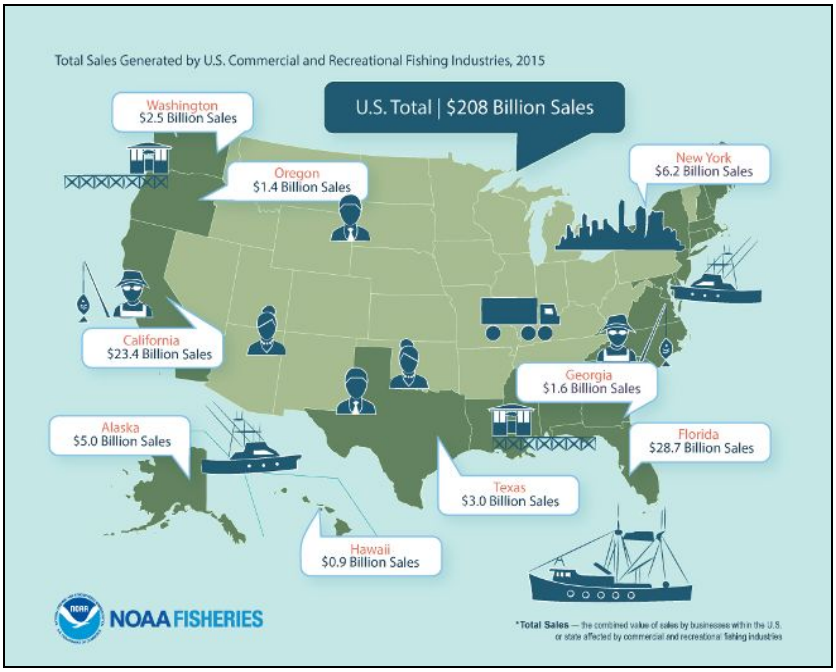
Fisheries and Aquaculture

- Each year, NOAA fisheries produces three annual reports on different aspects of the status of the United States marine fisheries: Status of the Stocks, Fisheries of the United States, and Fisheries Economics of the United States. Status of the Stocks summarizes the number of fish stocks that are on the overfished, overfishing, and rebuilt lists for U.S. federally managed fish stocks and fish complexes.[28]
- Fisheries of the United States provides a snapshot of data, primarily at the national level, on U.S. recreational catch and commercial fisheries landings and value.[28] Fisheries Economics of the United States provides a detailed look at the economic performance of commercial and recreational fisheries and other marine-related sectors on a state, regional and national basis.

Figures Below: Fisheries Economics of the United States 2015

- In 2015, the states with the greatest number of jobs in the commercial fishing and seafood industry were: Alaska, Massachusetts, Louisiana, Maine and Washington. Saltwater recreational fishing generated the greatest number of jobs in Florida, California, New Jersey and Texas in 2015.[29]
- In 2015, approximately 13 million recreational saltwater anglers took 61 million saltwater fishing trips around the country, spending $4.5 billion on fishing trips and $29 billion on durable fishing- related equipment.[29]
- Accurate, complete, and timely fishery dependent surveys are directly linked to commercial and recreational fishery stock quotas. In 2015, more than 9.7 billion pounds of finfish and shellfish were landed, valued at $5.6 billion, not including the downstream economic value. Fishery-dependent surveys increase the precision of stock assessments that allow for higher catch limits, more fish to market and economic gains to commercial and recreational fishermen and associated supporting industries.[29]





Prepared for the National Ocean Service, under Reimbursable Agreement RA-VXD2. Dr. Bahar Barami, principle investigator, p.8.

[28] National Marine Fisheries Service (2016) Fisheries of the United States, 2015. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2015. Available at: st.nmfs.noaa.gov/commercial-fisheries/fus/fus15/index

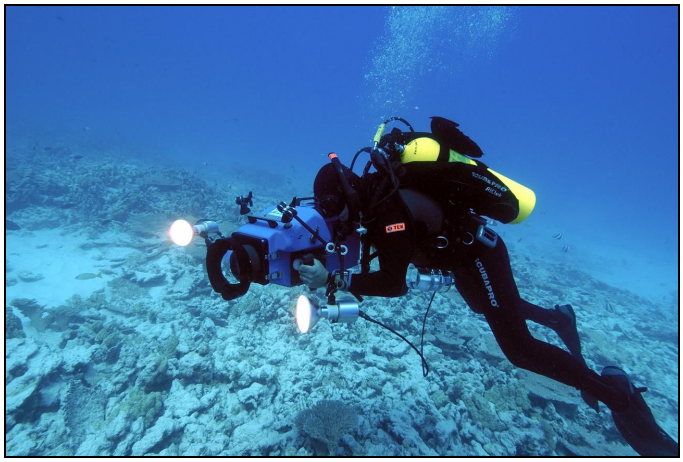
[29] National Marine Fisheries Service. (2017). Fisheries Economics of the United States, 2015. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/SPO-170, p.6. Washington, D.C.: U.S. Available at: st.nmfs.noaa.gov/economics/publications/feus/fisheries_economics_2015/index

- Oyster aquaculture helps meet the demand for seafood while improving water quality. For nitrogen removal, for example, the cost and removal efficiency provided by shellfish aquaculture compares favorably to removal by existing agricultural and stormwater best management practices.For example, the value of the nitrogen removal services provided by the aquaculture industry in Long Island Sound, based on an avoided costs method, is estimated to be $8.5 million annually at current production, with the potential to increase to more than $450 million if aquaculture production is expanded.[30] [31]

Oyster harvest in Shelton, Washington. (NOAA)

Coral Reef Ecosystems and Coasts

- NOAA, as a steward of the oceans' resources, protects the biodiversity of coral reefs and informs local officials on the best management practices to ensure that the reefs remain healthy and productive for economic, recreational, and cultural use.[32]
- Coral reef ecosystems provide many valuable services to the U.S. economy and our nation's coastal communities, supporting fishing, tourism, recreation, coastal protection and research. The value of these services has been estimated at $1.1 billion annually.[33]
- The coral reefs that support $100 million of commercial value of U.S. fisheries and more than $3 billion of local economies through diving, recreational fishing, hotels and restaurants will be detrimentally affected if time series data collected by NOAA vessels to assess reef health are not preserved.[34]
- Healthy coral reefs dissipate much of the force (97%) of incoming waves. These buffer shorelines from currents, waves, and storms are helping to prevent loss of life and property damage. Coastlines protected by coral reefs are also more stable in terms of erosion control.[35]
- There are 22 coral species listed as threatened and three species are considered endangered. The primary threats to coral reefs are global climate change, pollution from the land, and the impacts from unsustainable fishing.[36]



Rapture Reef sits within the Northwestern Hawaiian Islands Marine National Monument, which was created in 2006.

[30] Bricker, S. B., Ferreira, J. G., Zhu, C., Rose, J. M., Galimany, E., Wikfors, G., ... & Grizzle, R. (2015). An Ecosystem Services Assessment using bioextraction technologies for removal of nitrogen and other substances in Long Island Sound and the Great Bay/Piscataqua Region Estuaries. NCCOS Coastal Ocean Program Decision Analysis Series, (194). p.154.

[31] Rose, J.M., Bricker, S.B., and Ferreira, J.G. (2015). Comparative analysis of modeled nitrogen removal by shellfish farms. Marine Pollution Bulletin 91(1), 185-90.

[32] Office for Coastal Management NOAA (n.d.). Value of Coral Ecosystems. NOAA Coral Reef Conservation Program. Silver Spring, MD.

[33] Brander, L., van Beukering, P. (2013). The Total Economic Value of U.S. Coral Reefs: A Review of the Literature. NOAA Coral Reef Conservation Program. Silver Spring, MD. The figure cited above does not include non-use values (e.g., amenity, existence, and biodiversity values).

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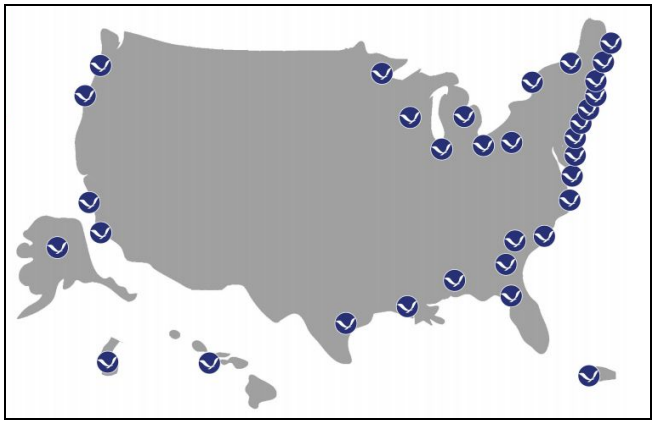
Sea Grant

- The NOAA Sea Grant program promotes research and collaborates with 33 university-based programs across the United States. In 2016, Sea Grant programs had an economic impact of $611 million[37].
- Sea Grant programs have contributed to the coastal economy for the last 50 years by utilizing community-based extension agents and researchers engaged in physical, biological, and social sciences.



Sea Grant is made up of 33 university-based programs.

- Texas Sea Grant worked with shrimpers to test fuel- saving trawl gear and transferred the new technology to the Texas shrimp fleet. The adoption of this new technology resulted in fuel savings of $3.1 million in 2016 for 431 shrimp trawl vessels, with total savings of $57.6 million in reduced fuel costs since the project began (2008-2016). These figures do not include savings associated with the reduced maintenance costs that also resulted from the adoption of this new technology.[38]
- Georgia Sea Grant supported community efforts that resulted in the Tybee Island Sea Level Rise Adaptation Plan. This plan enabled local homeowners to save $3 million on their flood insurance by helping to improve the City's rating under FEMA's Community Rating System (CRS). Measures adopted, in part, to adapt to future climate change reduced the community's current risk from severe weather.[39]
- Research funded by Washington Sea Grant showed that shellfish production in Puget Sound could remove as much nitrogen from the water as what is produced by 40,000 humans. This service could potentially cost $1.6 million annually if conventional treatment methods were used.[40]

In July 2007, NOAA partnered with Washington Sea Grant and the University of Washington Joint Institute for the Study of Atmosphere and Oceans to host the fifth annual NOAA Science Camp in Seattle.

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Coastal Communities

- Despite the fact that coastal counties account for 1/10 of total U.S. land area (except Alaska), slightly more than ⅓ of the nation's population live in shore-adjacent counties.[41]

In 2015, economic activity in the shore-adjacent counties accounted for:[42]

- **Gross Domestic Product**: $8.3 trillion (46 percent of U.S. total);
- **Employment**: 55.8 million (40 percent of
- U.S. total);
- **Wages**: $3.4 trillion (45 percent of U.S. total); and,
- **Business Establishments**: 3.9 million (41 percent of U.S. total).

- These coastal counties would be third in global GDP (behind the United States and China) if they were their own country.[42]

Visitors look out at California's historic Point Arena Lighthouse, which sits near the new northern boundary of the just-expanded Gulf of the Farallones National Marine Sanctuary. Credit: Matt McIntosh, NOAA.

California

- California is a vital contributor to the U.S. economy. In 2012, over $430 billion in goods moved through California ports to or from international markets.[43]
- Imports accounted for 75% of the trade total in California. The vast majority of this trade occurred with countries in East Asia and Southeast Asia. It is important to note that even imported goods are often related to job-producing production activities. In addition to the consumer goods imported through California's ports, a large share of the imports are intermediate goods — inputs used in production processes that take place in the United States.[43]

The Port of Los Angeles. In the U.S., where over half of us live along the coast and more than 78 percent of our overseas trade by volume comes and goes along our marine highways, the health of our coasts is intricately connected to the health of our nation's economy.

[41] National Ocean Service. (2013) National Coastal Population Report Population Trends from 1970 to 2020. Retrieved February 24, 2017, from oceanservice.noaa.gov/facts/coastal-population-report.pdf

[42] National Oceanic and Atmospheric Administration. (2017). Coastal Economy Pocket Guide. Retrieved March 27, 2018, from coast.noaa.gov/data/digitalcoast/pdf/socioecon-pocket-guide.pdf

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Conservation and Restoration Benefits

Marine Debris Removal

- Marine debris removal delivers significant economic benefits. A 2014 study reported that lost or derelict crab traps in the Chesapeake Bay result in the unharvested capture and mortality of blue crabs, resulting in potential annual economic losses to the fishery of $300,000. Other economically important fisheries are affected too, including Atlantic croaker, black sea bass, American eel, white perch, and catfish.[44]
- Marine debris can impact residents' decisions for where to recreate at the beach and ultimately reduce travel costs. For example, a 2014 study determined that Orange County, California residents would save $32 million in the summer months if the county provided cleaner beaches closer to home.[45]

NOAA PIFSC Coral Reef Ecosystem Program

Marine Sanctuaries

- The National Marine Sanctuaries were established to promote responsible, sustainable ocean uses that ensure the health and long-term productivity of our most valued ocean places. National Marine Sanctuaries are also important to the local economies in which they are located. Commercial fishing, research and recreational activities at all National Marine Sanctuaries generate $8 billion each year for local coastal communities.[46]
- National Marine Sanctuaries in California have large impacts for both recreational and commercial fisheries. In fact, one-third of California's commercial fish catch comes from its four National Marine Sanctuaries, generating an average (2010-2012) of $69 million in sales. "The impact of this activity across the economy as a whole generated nearly $114 million in output, $76.9 million in value added, $69.8 million in total income and supported over 1,800 full- and part-time jobs."[47] In this same time period, recreational fishing in California sanctuaries supported 1,400 jobs, generated $155.6 million in sales, 213 million in output and $75 million in income.[48]

[44] Bilkovic, D.M., Havens, K., Stanhope, D. and Angstadt, K. (2014). Derelict fishing gear in Chesapeake Bay, Virginia: Spatial patterns and implications for marine fauna. Marine Pollution Bulletin 80(1): 114-123.
[45] Leggett, C., Scherer, N., Curry, M., Bailey, R. and Haab T. (2014, June). Assessing the Economic Benefits of Reductions in Marine Debris: A Pilot Study of Beach Recreation in Orange County, California. p.3. Report prepared for the National Oceanic and Atmospheric Administration Marine Debris Division. Retrieved February 24, 2017 from marinedebris.noaa.gov/sites/default/files/publications-files/MarineDebrisEconomicStudy_0.pdf

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[48] National Oceanic and Atmospheric Administration Office of National Marine Sanctuaries. (2015, June). Economic Impact of the Recreational Fisheries on Local County Economies in California's National Marine Sanctuaries 2010, 2011 and 2012 (U.S. Department of Commerce, NOAA Marine Sanctuaries Conservation Series ONMS 2015-07) Washington, D.C.: U.S. Retrieved from, nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/science/socioeconomic/pdfs/california_rec_sanctuaries.pdf

Wetlands

- Coastal wetlands prevented more than $625 million in property damages during Hurricane Sandy and reduced property damages throughout the Northeast by 10 percent on average. In New Jersey alone, wetlands reduced more than $425 million in property damages. In Maryland, wetlands reduced damages by 29 percent.[49] The New Jersey Department of Environmental Protection estimated the total benefits from wetland ecosystem services is $36.6 million.[50]

NOAA's National Geodetic Survey established a high-accuracy vertical control network at the Chesapeake Bay Environmental Center to support coastal restoration, research, testing of new geodetic technologies, and monitoring of the effects of local relative sea-level rise. The network includes over a dozen geodetic bench marks distributed throughout the 510-acre wetland reserve near Graysonville, Maryland, with four deep-rod Surface Elevation Table (SET) marks located in the rapidly deteriorating marsh. Here, NOS employees install stainless steel rods into the ground as part of the process to install a SET. The SETs provide data to model the fate of the marsh in the face of rising water levels and ultimately provide insight into its restoration.

Habitat Restoration

Benefits of NOAA's habitat restoration activities, resulting from the American Reinvestment and Recovery Act (2009), include:[51]

- Restoring tidal wetlands, upland watersheds, and riverine habitats;
- Reestablishing 25,584 acres of habitat, opened 677 miles of stream for fish to reach spawning habitat, and removed 433,397 tons of debris from coastal habitats;
- Expending $154.1 million on projects to generate $260.5 million in economic output (sales) annually;
- Contributing $143.7 million in new or expanded economic activity nationwide including but not limited to wetland restoration in Muskegon Lake, freshwater tidal marsh in Skagit Delta, urban wetland restoration in Huntington Beach, California, and restoration and protection of oyster reef in Alabama;
- Enhancing downstream socio-economic benefits of restoration of healthier rivers and coastal habitats whose value ranged from $9.1 to $47.9 million from recreation and ecosystem services such as flood control and clean water.

NOAA Seeks Proposals That Will Restore Coastal Habitat, Create Jobs, Stimulate Economy

[49] Narayan, S., Beck, M.W., Wilson, P., Thomas, C., Guerrero, A., Shepard, C., Reguero, B.G., Franco, G., Ingram, C.J. and Trespalacios, D. (2017). Coastal Wetlands and Flood Damage Reduction: Using Risk Industry-based Models to Assess Natural Defenses in the Northeastern USA. Scientific Reports, volume 7, article number 9463. doi: 10.1038/s41598-017-09269-z

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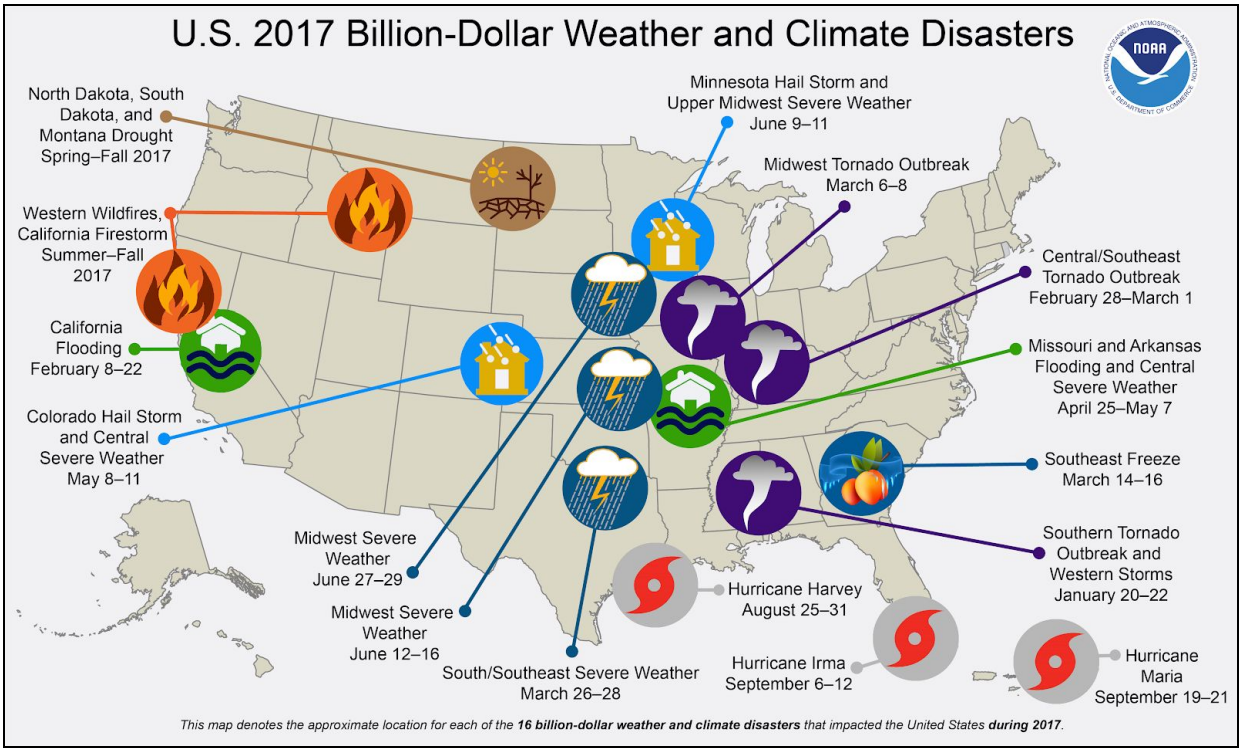
Economic and Social Impacts

General Weather-Related Damages and Losses

- There have been over 219 weather and climate events in the United States where damages were $1 billion or larger in the United States from 1980-2017. In total, these events surpassed $1.5 trillion.[52]
- During 2017, the United States experienced a historic year of weather and climate disasters. In total, the United States was impacted by 16 separate billion- dollar disaster events, including three tropical cyclones, eight severe storms, two inland floods, a crop freeze, drought, and wildfires. This year, 2017, ties 2011 for the highest number of billion-dollar disasters in a single year.[53]
- The cumulative damage of these events is $306.2 billion. The damage from Hurricanes Harvey, Irma and Maria alone are responsible for approximately $265 billion of the $306.2 billion. Each of these destructive hurricanes now joins Katrina and Sandy among the five costliest U.S. hurricanes on record.[53]
- In addition to the historic hurricanes, the United States had an extraordinarily damaging wildfire season where cumulative costs approached $18 billion. This annual cost triples the previous U.S. annual wildfire season cost record of $6 billion (in 2016) that occurred in 1991.[53]
- The year 2016 was the costliest year for storm damages, when compared to the four prior years. Storm losses totaled $175 billion, which was two-thirds greater than the previous year, 2015. In 2016, 70 percent of the losses were uninsured losses.[53]



Billion-Dollar Weather and Climate Disasters: Overview

[52] National Oceanic and Atmospheric Administration, National Centers for Environmental Information. (2018). U.S. Billion-Dollar Weather and Climate Disasters. Retrieved January 8, 2018, from ncdc.noaa.gov/billions/

[53] Munich Re. (2017, January 4). Natural Catastrophe Losses at their Highest for Four Years [Press Release]. Retrieved February 24, 2017, from munichre.com/en/media-relations/publications/press-releases/2017/2017-01-04-press-release/index.html

Lightning

- In a four-year period (2007-2011), local fire departments responded to a yearly average of over 20,000 fires that started by lightning. Each year, these lightning-related fires were responsible for an average of 9 civilian deaths, 53 civilian injuries and over $400 million in property damage.[54] Most of these fires occurred outdoors, but associated deaths, injuries, and property damages were mostly associated with home fires. Fires that were started by lightning peaked in the summer months.[55]

The Chemistry of a Thunderstorm: Weather.gov

Hurricanes

- This past year (2017) has been a historic year for U.S. hurricane damage. Hurricane Harvey flooded Houston with record-breaking rain, Hurricane Irma devastated the Florida Keys and U.S. Virgin Islands while Hurricane Maria destroyed much of Puerto Rico.[55] Each of these hurricanes will rank in the top five most costly hurricanes to affect the United States, joining Hurricanes Katrina (2005) and Sandy (2012). The damage from Hurricanes Harvey, Irma and Maria are responsible for approximately $265 billion.[56]
- Hurricane Sandy in 2012 was the worst storm to hit the northeastern United States since the Great New England Hurricane of 1938. Hurricane Sandy caused economic losses in the eastern United States of $65 billion ($69 billion in 2016), of which $27.3 billion were insured damages in 2012 ($29 billion in 2016).[56]
- Of the 15 most costly hurricanes in the United States, 12 have occurred between 2004 and 2017.[56] "The New Jersey governor's office calculated a total cost of $29.4 billion ($31.1 billion in 2016) in direct damages from Superstorm Sandy".[56]
- A recent study examined the risk of hurricane related storm surge for private property across the U.S. Atlantic and Gulf coasts by estimating the Reconstruction Cost Values (RCV) for each metro area. Regionally, 3.9 million homes were at risk of storm surge in the Atlantic Coast and the total RCV was $970 billion. Gulf Coast homes had similar estimates: 3 million homes were at risk of storm surge, totaling $593 billion for RCV.[57] When evaluating the state level risk, Florida (2.8 million homes) and Texas (0.5 million homes) ranked first and third, respectively, in terms of homes at risk to storm surge. States that have less coastline, but lower-lying elevations that extend further inland tend to have a high number of homes at risk to storm surge impacts. For example, Louisiana (808,000 homes) and New Jersey (470,000 homes) ranked second and fourth, respectively, for homes at risk to storm surge.[58]

NOAA Fisheries biologists save displaced wild dolphins after Katrina and Rita struck the Gulf Coast. More info: nmfs.noaa.gov/pr/health

[54] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Thunderstorms, Tornadoes, Lightning...Nature's Most Violent Storms: A Preparedness Guide, accessed at nws.noaa.gov/os/severeweather/resources/ttl6-10.pdf

[55] National Oceanic and Atmospheric Administration, National Centers for Environmental Information. (2017). U.S. Billion-Dollar Weather and Climate Disasters. Retrieved January 8, 2018, from ncdc.noaa.gov/billions/events

[56] Cooper, W., Garcia, F., Pape, D., Ryder, D., and Witherell, B. (2016). Climate Change Adaptation Case Study: Benefit-Cost Analysis of Coastal Flooding Hazard Mitigation. Journal of Ocean and Coastal Economics 3 (2), p.9. DOI: dx.doi.org/10.15351/2373-8456.1059

[57] CoreLogic. (2016, June 1). CoreLogic Storm Surge Analysis Identifies More Than 6.8 Million U.S. Homes at Risk of Hurricane Storm Surge Damage in 2016 [Press Release]. Retrieved February 23, 2017, from corelogic.com/about-us/news/corelogic-storm-surge-analysis-identifies-more-than-6.8-million-us-homes-at-risk-of-hurricane-storm-surge-damage-in-2016.aspx

Winter Weather

- The winter storms that struck the northeast United States and Canada in 2015 were costly for the insurance industry. Total losses for the year were $2.8 billion, while insured losses totaled $2.1 billion. Many of these damages occurred in the Boston metro area, where record breaking snow (totaling 90 inches) fell in a three-week period, causing numerous damages to infrastructure from uncommon snow loads.[58]
- Annual overall losses from winter storms averaged $1.4 billion for the period of 1993-2012 for the entire United States.[59] In comparison, U.S. winter storm overall losses totaled $4.4 billion in 2014 (insured losses were $2.5 billion) and $4.6 billion in 2015 ($3.4 billion for insured losses).[59]

Trawling in winter. Tough work! Working the trawl during a winter snow storm. Conducting an overwinter herring acoustic trawl survey. Alaska, Lynn Canal. 2005. Photographer: David Csepp, NOAA/NMFS/AKFSC/Auke Bay Lab.

Floods

- In August 2016, Louisiana experienced record rainfall and devastating flooding ensued. Approximately 60,000 buildings were destroyed. Overall losses amounted to $10 billion, making this the costliest disaster for the United States since Hurricane Sandy in 2012.[60]

Spring Outlook: Moderate flood risk for drenched Louisiana, east Texas

Wildfires

- The historic United States wildfire season of 2017 began as numerous wildfires burned across many western and northwestern states. “Montana in particular was affected by wildfires that burned in excess of 1 million acres. These wildfire conditions were enhanced by the preceding drought conditions.”[61]
- The most costly damage of the wildfire season occurred in October in California’s wine country. This was followed by California’s largest wildfire on record — the Thomas Fire — in December. In total, these destructive wildfires damaged or destroyed over 15,000 homes, businesses and other structures across central California and caused 44 deaths.[1] In addition to the historic hurricanes, the United States had an extraordinarily damaging wildfire season burning more than 9.8 million acres in 2017. The cumulative costs approached $18 billion, which tripled the previous U.S. annual wildfire season cost record of $6 billion (in 2016) that occurred in 1991.[53]

[58] Munich Re. (2016, January 4). 2015 U.S. Natural Catastrophe Losses Curbed by El Niño; Brutal North American Winter caused Biggest Insured Losses [Press Release]. Retrieved February 24, 2017, from munichre.com/us/property-casualty/press-news/press-releases/2016/160104-natcatstats2015/index.html

[59] Munich Re. (2014). 2013 Natural Catastrophe Year in Review [PowerPoint Presentation], slides 23 and 24. Retrieved February 22, 2017, from munichreamerica.com/site/mram/get/documents_E1433556406/mram/assetpool.mr_america/PDFs/4_Events/MunichRe_III_NatCatWebinar_012014.pdf

[60] Munich Re. (2017, January). Natural Catastrophes in 2016. Retrieved February 23, 2017, from munichre.com/topics-online/en/2017/topics-geo/overview-natural-catastrophe-2016

[61] National Oceanic and Atmospheric Administration, National Centers for Environmental Information. (2017). U.S. Billion-Dollar Weather and Climate Disasters. Retrieved January 8, 2018, from ncdc.noaa.gov/billions/events/US/1980-2017

Marine Transportation

- The estimated average annual loss to container shipping (lost containers and damage to vessels) from extratropical (mid latitude) storm conditions was $250 million per year in the North Pacific and $120 million per year in the North Atlantic.[62]
- The estimated average expected annual losses to bulk shipping operations from Nor'easters, blizzards and low-pressure rain storms in these regions were at least $150 million per year. The World Shipping Council estimated that during 2008–2013, less than 1,700 containers per year were lost at sea.[63]

Robert Schwemmer, NOAA National Marine Sanctuaries

Tourism

- The State of New Jersey suffered significant tourism revenue losses from Superstorm Sandy. The U.S. Department of Commerce (2013) estimated that from July to September, New Jersey lost $950 million of tourism revenues ($989.9 million in 2016). These revenues are distributed among accommodations ($287.2 million), food services and drinking establishments ($217 million), retail ($46.8 million), recreation ($106.5 million), air transportation ($30.1 million), and other modes of transportation and support activities ($141 million). "The total annual value of tourism in New Jersey's protected area is estimated at $121.6 million based on total area."[63]

On both coasts and on thousands of beaches, the ocean attracts surfers from around the world.

[62] World Shipping Council (2014). Containers Lost at Sea 2014 Update, p. 2. Retrieved April 12, 2017, from worldshipping.org/industry-issues/safety/containers_lost_at_sea_-_2014_update_final_for_dist.pdf

[63] Cooper, W., Garcia, F., Pape, D., Ryder, D., and Witherell, B. (2016). Climate Change Adaptation Case Study: Benefit-Cost Analysis of Coastal Flooding Hazard Mitigation. Journal of Ocean and Coastal Economics 3(2), p.9. DOI: dx.doi.org/10.15351/2373-8456.1059

Key Definitions

Core Based Statistical Area (CBSA) – It consists of the county or counties or equivalent entities associated with at least one core (urbanized area or urban cluster) of at least 10,000 population, plus adjacent counties having a high degree of social and economic integration with the core as measured through commuting ties with the counties associated with the core (U.S. Census Bureau/U.S. Department of Commerce, census.gov/geo/reference/gtc/gtc_cbsa.html).

Endangered Species – Any species that is in danger of extinction throughout all or a significant portion of its range (U.S. Fish & Wildlife Service, fws.gov/endangered/laws-policies/).

Estuary – An area where a freshwater river or stream meets the ocean. In estuaries, the salty ocean mixes with a freshwater river, resulting in brackish water. Brackish water is somewhat salty, but not as salty as the ocean. (National Oceanic and Atmospheric Administration, National Ocean Service, oceanservice.noaa.gov/facts/estuary.html).

Gross Domestic Product (GDP) – The value of the goods and services produced by the nation's economy less the value of the goods and services used up in production. GDP is also equal to the sum of personal consumption expenditures, gross private domestic investment, net exports of goods and services, and government consumption expenditures and gross investment (Bureau of Economic Analysis, U.S. Department of Commerce, bea.gov/newsreleases/national/gdp/gdpnewsrelease.htm).

National Spatial Reference System (NSRS) – A consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States. NOAA's National Geodetic Survey manages NSRS (National Ocean Service, National Oceanic and Atmospheric Administration, oceanservice.noaa.gov/facts/nsrs.html).

Physical Oceanographic Real-Time System (PORTS): A program of NOAA's National Ocean Service that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions (National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services, nws.noaa.gov/om/marine/ ports.htm).

Replacement Cost (RC) Value – Replacement Cost is defined as the cost to replace an entire building with one of "equal quality and utility. Replacement costs, often calculated using outdated square-foot or unit- count methods, are based on prices for labor, materials, overhead, profit and fees that are in effect prior to the loss (Independent Claims Service, Inc., propertyinsurancecoveragelaw.com/files/2017/06/replacevrecon_handout.pdf).

Storm-Based Warning (SBW) – Threat-based polygon warning that shows the specific meteorological or hydrological threat area and are not restricted to geopolitical boundaries (NOAA National Weather Service, nws.noaa.gov/sbwarnings/).

Threatened Species – Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (U.S. Fish & Wildlife Service, fws.gov/midwest/wolf/esastatus/e-vs-t.htm).

Willingness-to-Pay (WTP) – The maximum amount an individual is willing to give up to receive other goods and/or services in return. It is a key to economic theory of value.

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